Marine Physical Laboratory

Deep Ocean Benchmarks for GPS Survey

Fred N. Spiess
Principal Investigator

Final Report to
National Aeronautical & Space Administration
Grant NAGW-2026
for the Period 03-15-91 - 12-31-91

MPL-U-8/92
January 1992

University of California, San Diego
Scripps Institution of Oceanography

Deep Ocean Benchmarks for GPS Geodesy

Fred N. Spiess (Principal Investigator)

Final Report to the National Aeronautical and Space Administration for Grant NAGW-2026 for the Period 03-15-90- 12-31-91

We have successfully carried out the work funded in our grant NAGW-2026 culminating in the initial implementation of an ocean geodetic GPS/Acoustic approach to tracking the motion of the Juan de Fuca Plate, and related studies of convergence at the Juan de Fuca/North American Plate boundary off Vancouver Island. During the period from 27 May through 7 June MPL personnel (with assistance from PGC and JPL) installed long lived precision transponders at two sites and made acoustic range measurements to them from the surface float while the JPL group made GPS measurements at their three float-mounted antennas and ten global tracking stations. PGC and USGS personnel carried out simultaneous GPS observations at nearby on-shore sites.

Given that this constituted the first use of our precision transponders outside of the Santa Cruz Basin environment and the first deployment after implementation of modifications designed to achieve five year transponder life, some performance surprises were met and at-sea modifications made to counter them. Operational procedures also had to be developed for transponder launching, float launch and recovery, and maneuvering to control float position during observation periods. While it is clear that further development on all aspects of the full seagoing system and its operation are essential, nevertheless monitoring of the acoustic and GPS data indicate that, within the three groups, we have the data necessary for first epoch determination of benchmark positions and for evaluation of current system performance and application of this approach.

In preparation for the seagoing work, all elements of the system were tested to the extent possible ashore, including running the modified transponders with dummy loads for 24 hour periods at low temperature, assembly of the float (with JPL modifications to raise the antennas further above the water) and careful measurement of its dimensions. With regard to the float, we continue to be indebted to the Scripps Institution of Oceanography Physical Oceanography group for the loan of the doughnut buoy that provides most of the float's buoyancy.

The process of float launch and recovery had been gone through twice alongside the pier. Our original plan had been to use the tow line for lowering the float in and lifting it out. On this ship, however, equipment is launched and recovered by the ship's force, and the Captain chose to use an approach in which the float is lowered in by an auxiliary line that is disconnected once the float is in the water. This simplifies the launch process, but means that a boat must be put into the water to attach the crane for recovery.

Transponders were launched by suspending them below an electrically operated release hook at the end of 0.25" wire (with single conductor core). In this manner they could be lowered to the sea floor and checked out prior to release. This was essential because we did not want to attach any recovery flotation for fear near bottom currents might produce local movement or tilting of the transponders during their five- year life on the sea floor. This approach allowed us to detect and correct transponder problems prior to release.

Selection of the shelf site was made to provide control for various models of the convergence process. Pragmatic aspects, however, emerged, in that it became clear that there was considerable risk that bottom fishing activity would disturb the transponder. Since the trawlers primarily work along contour lines and tend to avoid obstructions, we elected to place our unit close to the edge of a charted explosives dumping area at a depth (150 m) corresponding to a contour line that passes through the dump site.

The Juan de Fuca Plate tracking site had been selected as 488°904'N, 1268°9-46'W on the basis of a PGC seismic reflection line. The position chosen was seaward of any seafloor or subbottom distortion discernable in their data. No detailed seafloor morphological information was available. Upon arrival at that site we made a small box echo sounder survey, and discovered we were in a zone of low relief features (9~8 10 m) that indicated past local bottom disturbance (slumping or erosion). We thus continued our survey to the northwest, onto smooth topography, eventually selecting a square approximately 4 km on a side, with no indications of any topographic irregularities and gently sloping to the south (1 m in 4 km). Sides of the square were oriented N/S and E/W with the SE corner at 488°9-10'N, 1278°9- 10'W. This put us a few miles west of a munitions dump site (between 488°9-10' and 20'N, 1268°9-55' and 1278°9-05'W) that had been surveyed by the MPL group in 1971.

Arriving at the shelf site at about 0400 (local time) on 28 May, we made an echo sounder survey of the area and began the transponder launch process. Although the transponder performed well while being lowered, as soon as it was close to the bottom it stopped replying (a repeatable problem). The unit was brought on deck and replaced by a second one, which acted in the same manner. This was not a situation that had been observed in any of our previous operations (Santa Cruz Basin - 2,000 m depth, flat sea floor). Since the effect was repeatable we chose to assign it to some sort of interference phenomenon, and released the transponder onto the sea floor. As we moved away, replies returned; however, when we put the float in the water, the returns were badly masked by reverberation (inadequate signal to reverberation level to allow precise travel time measurements). We thus moved out beyond optimum range, to where the S/R ratio was adequate and gathered simultaneous GPS and acoustic data in the 0000 to 0600 (29 May) window, working at ranges of 600 to 1000 m (in 150 m water).

With wind and sea building the morning of the 29th we (ship's force and scientific party) recovered the float, made a CTD profile[1] and then rendezvoused with another Cana- dian research ship (Parizeau) to pick up some computer software essential for full CTD operation. At this point we decided to wait out the weather by carrying out a simpler operation planned for this same cruise: deployment of two transponders near 488°9-30'N, 1288°9-40 W for use by the Ocean Drilling Program in July. This involved launching the ODP units over the stern, locating them in relation to an existing net, and then recovering five other transponders. This work (including steaming into the weather at 7.5 to 8 knots to the site) was completed by about 2000 on the 30th and we were on the originally chosen Juan de Fuca Plate site by 0600 the next morning.

After locating and surveying an appropriate site, as noted above, we started transponder launching. The first unit lowered to the sea floor (this time in 2600 m depth) behaved in the same manner, with loss of replies when on the bottom. Given our previous experience, we decided to release it. In this case, however, returns were not received when we moved away from the point directly above the transponder. Fortunately, although our geodesy program only had 5 complete transponders, we had brought spare parts and a pressure case borrowed from a different project, and thus still had a capability to field 4 units at the deep site, as planned.

Loss of replies during launch was clearly unsatisfactory, thus, after analyzing a variety of possible causes we decided on an alteration of the signal recognition criterion and implemented that, requiring opening all four units and replacing a chip with a re-programmed element. This solved our problem, giving reliable operation for the remainder of the trip.

Unfortunately, the need to have the greatest possible acoustic output from the transponders meant that we could not test them under full power unless they were subjected to substantial hydrostatic pressure. This is a problem that we will have to remedy in future designs, since the on site transponder launch process was also our most realistic test opportunity. This meant use of time on station, since, after completion of the recognition circuit modifications, several of the units were lowered, tested and had to be brought back on board to correct defects.

1. An instrument that measures seawater conductivity, temperature and pressure. From its data, profiles of salinity, density and sound velocity vs. depth can be deduced.

Release procedures were also sharpened during this period and four properly operating and located precision transponders were on the sea floor by noon on 2 June. Float launching took place immediately after that and we were able to collect data (GPS and acoustic) at the center of the array for the last 2 hours of the 1000-1600 GPS window of availability. The float was left in the water and observations resumed at 0000 on 3 June.

At about 0145 the umbilical cable went under the ship and was severed by the propeller. It was not feasible to retrieve the float under these conditions in the dark, however the ships force completed recovery by 0800. A replacement composite cable was assembled and wired onto the float components. The float was back in action by 1300, giving about another 3 hours of observation time, this time just south of the array.

From this point on, the operation went as planned, with successive 6 hour observation periods west, north, east, and in center, terminating at about 1600, 5 June, with float recovery (took an hour in rough seas).

We then steamed back to the shelf site, while making alterations to the float-mounted sonar system to reduce its transmit level and receive sensitivity to be a better match to the shallow, reverberant conditions. These alterations were successful and data were collected for two six hour periods as the float was maneuvered to various azimuths and horizontal ranges in the 200-400 m bracket.

The collection of GPS data from the buoy-mounted antennas was quite successful. A modification to the buoy which raised the antennas an additional 1.5 m above the waterline substantially reduced data loss due to washovers. It is expected that phase connection across the periods of loss-of-lock will be accomplished routinely, using the accurate P-code data. A more troublesome feature of GPS operation on the current buoy is the presence of significant tilt angles, which cause losses of signal for satellites at low eleva- tions. This limits tropospheric parameters estimation accu racies. The next-generation buoy will be designed to have much smaller roll angles. The only significant interruption of GPS data occurred, as discussed above, when the umbilical was severed by the ship's propeller.

Rogue receivers were operated at a 1-second data rate at PGC and Ucluelet, both on Vancouver Island, to match the buoy receiver rates allowing cancellation of satellite clock errors. These data were collected by PGC personnel without major problems. TI 4100 receivers were operated at Neah Bay and Victoria, by USGS and PGC personnel, respectively. Other Canadian Rogue tracking receivers were operated at Penticton, Yellowknife, and Algonquin Radio Observatory.

In addition, a worldwide network of ten Rogue receivers, coordinated by Ruth Neilan, was operated to provide data for GPS satellite orbit determination.

Environmental data were collected at various times throughout the operation. Because of the need to operate the sound velocity meter without a conducting wire, a data logging package had been built (for a different but collaborating project, since this element was not in the current budget). The logger gave problems and thus only 2 profiles were obtained, both at the deep site. PGC had obtained a precision CTD, however, and that was our primary source of data. At the deep site, observations were limited at first because of lack of ability to control the float in relation to the ship in such manner as to insure that the umbilical and CTD wire would not interfere with one another. These ship handling problems were eventually worked out and four profiles, well-separated in time were obtained. Upon return to the shelf site we made a CTD cast about every 3 hours for the 16 hours on- station.

Shipboard looks at the data indicate that we will have more than enough to achieve our goals of evaluating accuracy and establishing initial locations. Presuming continuation of the program we look forward to the data analysis activity and to investigation of modifications in hardware and operating procedures to improve our efficiency in carrying out the at-sea operations.

We are indebted to Capt. John Anderson of CSS John P. Tully, and his crew, for their cooperation and support, and look forward to further operations with them.